Baryon Junction Stopping at the SPS and RHIC via HIJING/B *

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The systematic study of baryon stopping and hyperon production in pp, pA, and AA collisions is essential in order to differentiate the sought after new physics of dense equilibrated matter from non-equilibrium multi-particle production dynamics. Baryon stopping refers to the transport of baryon number in rapidity space away from the nuclear fragmentation regions and is measured through the single inclusive rapidity distribution of protons and hyperons.

In this work we test a third model of baryon transport recently proposed by Kharzeev and based on a long dormant Rossi-Veneziano baryon junction Regge exchange model. In this approach, the baryon number is traced by a non-perturbative baryon junction of topological nature. The special theoretical appeal of that idea arises from the form of the baryon wavefunction in QCD. The requirement of gauge invariance of the nonlocal operator creating a baryon naturally leads to the concept of a baryon junction:

$$B(x_1,x_2,x_3,x_J) = \epsilon^{ijk}\left[P\exp\left(ig\int_{x_1}^{x_J}dx^\mu A_\mu\right) q(x_1)\right]_i \left[P\exp\left(ig\int_{x_2}^{x_J}dx^\mu A_\mu\right) q(x_2)\right]_j \times \left[P\exp\left(ig\int_{x_3}^{x_J}dx^\mu A_\mu\right) q(x_3)\right]_k \quad (1)$$

The baryon junction is a vertex at x_J where the three gluon Wilson lines emanating from the three valence quarks (in SU(3)) must join in order to form a gauge invariant operator. In a highly excited baryonic state, the three valence quarks fragment via multiple $q\bar{q}$ into mesons leaving three sea quarks eventually around the junction to form the observed final baryon. This is the sense in which the junction traces the baryon number. Being a purely gluonic configuration, the junction may be easily transported into the mid-rapidity region. The fragmentation of the end point valence quarks naturally leads to a three beam jets, very similar to the previous mechanisms considered. The primary advantage of this mechanism is that Regge phenomenology can be used to estimate the inclusive inelastic cross section for this process. From $p\bar{p}$ and pp data, the junction-anti-junction exchange is characterized by a trajectory with intercept, $\alpha_{J\bar{J}}(0) \approx 1/2$. This leads immediately to a $\cosh y/2$ rapidity dependence and an $1/\sqrt[4]{s}$ energy dependence.

The unique prediction of this mechanism is that fragmentation of the valence quarks down to the junction is expected to enhance hyperon production by a factor of 3 just from the random combinatorics of s vs u, d sea quark production. In addition, from the random addition of three sea quarks, the transverse momentum of the final baryon is automatically enhanced by a factor of $\sqrt{3}$.

Given these interesting coupled consequences of the baryon exchange mechanism, we have chosen to implement this model in a new version HIJING, called HIJING/B.

In HIJING/B, baryon junction stopping is implemented using a “Y” string configuration for the excited baryons in which the baryon junction and produced baryon are distributed as noted above. The resulting three beam jets are treated as $q\bar{q}$ configurations.

For each nucleon-nucleon interaction, a $\sim 60\%$ probability is given that only one of the two nucleons will have its baryon junction stopped in the central rapidity region. Baryon excitations without junction exchange are taken to be standard $(qq) - q$ strings for fragmentation purposes. The junction exchange probability is fitted so as to reproduce the $p+p$ valence proton data.

We find that this is sufficient to account for the midrapidity valence baryon data in pA and AA. The model naturally leads to large enhancement of the $p_\perp$ slope as well as of the yield of hyperons. However, the preliminary $\Lambda - \bar{\Lambda}$ yield in $PbPb$ is still underestimated without multiple final state interactions.

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